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The undersigned hereby certify that they have read and recommended to the Committee on Graduate Studies for acceptance a thesis on "Replaceable Base, Hydrogen and Base-Holding Capacity of Alberta Soils", submitted by M. Holowaychuk, B.Sc. in partial fulfillment of the requirements for the degree of Master of Science.

Approved: A. G. Galt

Approved: C. M. Jones

Approved: J. D. Newton

Approved: J. R. Fryer



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Nicholas Holowaychuk

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April, 1931.

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HISTORICAL.

The study of base exchange in soils dates back to 1850 when Way published his first paper. His observations and conclusions as summarized by Hissink (8) are:

- (1) "The salt is not absorbed as a whole, but only the base.

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REPLACEABLE BASES, HYDROGEN AND BASE-HOLDING
CAPACITY OF ALBERTA SOILS.

by

N. Holowaychuk.

INTRODUCTION.

The fact has long been observed that when a soil is treated with a neutral salt solution it fixes the base of the salt with a corresponding release of a number of other bases. This phenomenon with its apparent simplicity has been shown to be of considerable importance in explaining many of the problems confronting the soil scientist. Considerable work has been done at various institutions on this continent and in Europe, but no work has been reported showing the relationship of replaceable bases in Alberta soils. The problem reported in this thesis was undertaken to show how the soils of Alberta compare in themselves and with those from other parts of the world in this respect.

HISTORICAL.

The study of base exchange in soils dates back to 1850 when Way published his first paper. His observations and conclusions as summarized by Hissink (9) are:

(1) "The salt is not absorbed as a whole, but only the base.

(2) The filtered liquid contained the acid of the given salt united to lime.

(3) The quantity of lime acquired by the solution corresponded exactly to that of the base removed from it - the action was therefore a true chemical decomposition.

(4) The combination between the soil and the base was rapid if not instantaneous, partaking therefore of the nature of the ordinary union between an acid and an alkali."

Way also noted that the active portion of the soil with respect to base exchange occurred in the clay part.

These conclusions are classical in nature and may be looked upon as representing the main principles of base exchange in soils. Following Way there has been little work done or at least made available until about 1920 when Gedroiz (8) and Hissink (9) made their findings known. These two may be looked upon as the first of the modern school of workers in the field.

The study of base exchange in soils as developed by the present workers seems to resolve itself into four lines of activity, viz:

(1) Determining the type of reaction or reactions accompanying the base exchange in soil - the chemistry of ion exchange in soils.

(2) Isolation and identification of the soil fractions and their various components which have base exchange properties. This fraction of soil is usually referred to as the base exchange complex.

(3) Studying the effect of weathering and degradation of soil on its base exchange properties, and its pedological significance.

(4) Studying the agricultural significance of base exchange in soil.

Type of Reaction

The rapidity of reaction has led the early workers to believe that base exchange took place as physical absorption by the soil colloids or some other type of surface reaction.

Gedroiz (8) favored a physico-chemical explanation whereby the reaction occurs on the surface of a slightly soluble compound that is ionized slightly when brought in contact with a liquid phase. The differences between the physical absorption and physical chemical reaction are given by Gedroiz as:

(1) "In physical absorption the absorbed substance remains in liquid phase and can be washed out".

(2) "Only the cation is absorbed in a physico-chemical reaction".

(3) "Physical absorption would deplete the solution of some of its equivalents".

He also has shown that the replacing power of cations varies with atomic weight and valency. He found that hydrogen was most active while with the basic cations the activity increased with increase in atomic weight and in valency.

Hissink (9) assumed a chemical attraction between cations and the anion of the base exchange substance. These

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THEORY OF ADSORPTION

The rapidity of reaction has led the early workers to believe that these exchange reactions are typical of the solid-solvent interface. The solid colloids or some other type of surface reaction. Gabor (8) favored a physical-chemical reaction whereby the reaction occurs on the surface of a slightly soluble compound that is limited slightly more than it is with a liquid phase. The differences between the physical adsorption and physical chemical reaction are given by Gabor.

(1) "In physical adsorption the adsorbed substance remains in liquid phase and can be washed out".

(2) "Only the cation is adsorbed in a physical-chemical reaction".

(3) "Physical adsorption would lead to the formation of some of the active centers".

He also has shown that the physical adsorption of ions varies with atomic weight and valence. The physical adsorption was most active while with the same cation and a fixed amount of adsorbent. He showed a physical adsorption of ions with increasing atomic weight and in valence. Haskins (9) showed a physical adsorption of ions on the surface of the solid adsorbent. These

were ionized and the cations remained as a layer outside the anion.

Mattson (21) showed a correlation between the amount of exchangeable bases in soil colloids and the methylene blue necessary to bring the colloid to its isoelectric point. This suggested absorption of bases due to amphoteric properties of certain colloids.

Kelley and Brown (12) have shown that all colloids do not exhibit base exchange properties, the best example being kaolin.

Kerr (19) has shown recently that base exchange reaction in soils can be represented mathematically by a law of mass action which behaves similarly to one developed for chemical reaction. This seems to give the best explanation of the type of reaction occurring in base exchange and indicates more or less a chemical nature.

However, when a complex mixture like the soil is considered it may be very seldom that a reaction of only one kind occurs. It is more reasonable to assume that there are a whole series of reactions taking place with the organic matter, the various soil minerals as well as the simple electrolytes and present a more or less complex mass as mentioned by Kelley and Chapman (14). There may be also a certain amount of physical absorption and straight solubility occurring simultaneously with ion exchange.

Isolation and Identification of Complex.

Way was the first to notice that in a purely mineral soil the properties of base exchange were exhibited by the clay fraction of the soil. Gedroiz (8) attributed the properties to certain humic and "zeolitic" substances in soil, the "zeolitic" portion being a complex alumino-silicate. Hissink (9) also regarded the base exchanging fraction of the soil as being alumino-silicic and humus acids. The same view was held by Kelley (17) originally but has been somewhat modified in his latest paper (15). Kelley also marked the similarity between the mineral complex and zeolites and for a time had supported the view that base exchange properties in soils were due to zeolites. Magistad (20) pointed out the similarities between the base exchange complex in soils and certain artificial zeolites with respect to their properties. A very good point was brought up here, viz. that artificial zeolites disintegrated somewhat similarly to the base exchange complex. The occurrence of this process in base exchange complex has been verified by Gedroiz, who attributed formation of podsoles and alkaline soils to the above reaction.

The most satisfactory work in this field has been done only recently. Kerr (18) and Truog and Chueka (30) working at Wisconsin have made some important contributions. Kerr used a clay-bentonite as source of his complex. This correlated very well with that of soil in exchange equilibria.

He showed that the portion of bentonite showing base exchange properties was fairly resistant to acids and also that the $\frac{\text{SiO}_2}{\text{R}_2\text{O}_3}$ ratio corresponded to that of feldspar. He did not favor the idea that zeolites were responsible for exchange of bases in soil, the main points being:

(1) Exchange equilibria for zeolites gave a higher constant than the soil did.

(2) Exchange complex of soil is more stable than zeolites as shown by resistance to acids.

(3) Separation of a fraction in soil corresponding to zeolites in sp. gr. did not remove all of the base exchange properties of soils.

Kerr was also able to separate fractions from bentonite and soil by leaching with acid and then removing the electrolytes by washing. The complex came out as colloid and was reprecipitated with electrolytes. The two corresponded identically on chemical analysis.

Continuing the work of Kerr (18), Truog and Chueka (30) isolated the complex from bentonite and soil. They also were able to prepare similar complex from weathering of feldspar rock. This may be a very important item in explaining the distribution of the complex in soils, viz. that it was derived from feldspar rocks. They used a basic dye, which is a very sensitive test for the complex, and found it to be colloidal material on the surface of crystalline mineral particles.

The latest contribution in this line came from Kelley, Dore and Brown (15). In this investigation a number of properties of natural zeolites and bentonite were compared. It was shown that:

(1) Base exchange capacity of bentonite could be increased by grinding, hence was located internally. The bases are all located on the surface in zeolites.

(2) Very little of the magnesium of bentonite can be replaced, while in zeolites nearly all of it can be replaced. The same could be said of the bases in general.

(3) The complex is fairly stable even when saturated with hydrogen. This is not true of zeolites.

(4) Bentonite retained its exchange properties even after being heated up to 750° C. Zeolites lost theirs at about 350° C.

A series of X-ray examinations were made of bentonite, soil colloids and zeolites. Some agreement was obtained between soil colloids and bentonite, but not with zeolite.

From the above evidence it seems that the complex is a mineral, fairly complicated in composition but rather stable. It is evidently one of the secondary products of weathering, but has as yet not reached the simplest stage. It is also reasonable to assume that very few zeolites would survive the long weathering that a soil has been subjected to.

Pedological Significance of Base Exchange Studies.

Gedroiz was the first to notice that if a soil was leached with water the basic cations were gradually removed and gave rise to an acidic complex. This was noticed to be unstable physically and chemically, showing a tendency either to be leached out as a colloid or be disintegrated into oxides of Al, Fe and Si. The acidic properties of the complex are due to absorbed hydrogen. Page (23) mentions three types of soil acidity, viz. "hydrolytic" "exchangeable" and "active". He speaks of "hydrolytic" acidity as that extracted with an alkaline salt like sodium acetate. The "exchangeable" acidity is extracted with a neutral salt while "active" acidity is due to ionization of the complex, i.e. acidity extracted with water.

These different types of acidity are really only different degrees of saturation of complex with hydrogen. Gedroiz (8) found hydrogen in some badly leached soils to be ten times that of the basic cations. The processes of replacing basic cations with hydrogen and moving of colloids are ones of podsolization.

Gedroiz also showed in some of his early papers that soil degradation may occur through having the complex saturated with sodium. As is well known the sodium saturated complex hydrolyses when not prevented by common ion effect of sodium salts. Thus on hydrolyses the NaOH may be gradually removed leaving the H complex (Soloti) as Gedroiz calls it.

It may be said that Gedroiz has actually suggested a scheme of soil classification based on the degree of saturation and also on the basic cation content of the soil. Gedroiz system of classification is given by Afanasiev (1). In this system soils that are unsaturated with bases are put into the sub-groups Podzols and Laterites. The base saturated soils are subdivided into the chernozem and alkaline groups.

The kind of cations in combination with the complex has been shown to exert a very important influence on the physical condition of the soil. Such workers as Kelley and Brown (12), Gedroiz (8), Hissink (9) and Bayer (3) have shown that different cations have different power of dispersing the soil colloids. The order of cations grouped according to their power of dispersion is $\text{Na} > \text{NH}_4 > \text{K} > \text{Mg} > \text{H} > \text{Ca} > \text{Ba}$. Parker and Pate (24) found that soils saturated with monovalent bases have lower heat of wetting, and with the exception of sodium absorb less water than soils saturated with divalent bases.

Thus it is seen that the kind of cation has a very marked influence on the physical condition of the colloids and thus indirectly on the soil.

The Agronomic Significance of Base Exchange.

The agronomic importance of base exchange has been shown in many ways. Hissink correlated the physical condition of the soil with its exchangeable cations. He found that ratio of divalent to univalent bases gave a soil of poor tilth

when it was 65:35 and a good soil when it was 80:20.

Robinson and Williams (28) have shown that available calcium varies directly as the replaceable calcium and also the saturation of the soil.

Kelley and Brown (12) obtained replaceable Al, Mn and Fe in some of the acid soils. Page (23) has also shown that replaceable Al may be high in soils that are unsaturated, and that it may exist as a cation combined with the complex in some cases. Turner (31) working in Trinidad found that the soils there with an unsaturation greater than 38% gave a bad physical condition. Pierre (26) was able to derive a rather good correlation between plant injury and degree of unsaturation in the soil. He found also that replaceable aluminum was present in unsaturated soils. Robinson and Williams (28) found that if the exchangeable calcium was high the degree of saturation is less vital than where it was low.

As it is shown above the question of soil acidity and base exchange are very closely related. The acidity is mostly due to the degree of unsaturation of the complex. The degree to which it ionizes and the ratio of hydrogen ions to the basic cations determine the pH of the soil. If the complex is sufficiently unsaturated it may decompose into oxides of Si, Al and Fe, and may take on a more dispersed state than it would if it was saturated with calcium.

Base exchange plays an important part in fertilization of soils. Kelley (16) has shown that potassium fertilizers

were fixed and certain difficulties were experienced in getting it down to some of the deeper-rooted plants. Ammonium salts were also shown by Kelley to be fixed similarly to potassium. This may be an important process in retaining the ammonium fertilizers in the soil until released by microorganisms. Also, if a soil is high in replaceable bases, more of them will be released by the slightly acidic water arising from CO_2 and nitrification and sulfonation. The problem of alkali is likewise primarily one of base exchange. If much sodium is present the soil assumes a very dispersed state, and coupled with this the soil solution may be high in sodium salts. Gedroiz has derived the fact that when a sodium saturated soil has the salts removed the complex undergoes hydrolyses giving rise to alkaline conditions or "solonetz" as he calls it. Hence, the method of reclaiming alkali soils should be one by which the sodium will be replaced by calcium besides washing out its salts.

A rather fitting statement was made by Kelley (16) in closing his paper on the Agronomic Significance of Base Exchange. "It seems safe to assert that base exchange is one of the important and widely applicable principles of soils, but, as stated at the outset, base exchange neither applies to nor explains everything about the soils. Its investigation has nevertheless given us a much better understanding of some very important aspects of soils. A good working knowledge of base exchange will certainly prove valuable to agronomists".

DESCRIPTION OF THE SOILS OF ALBERTA.

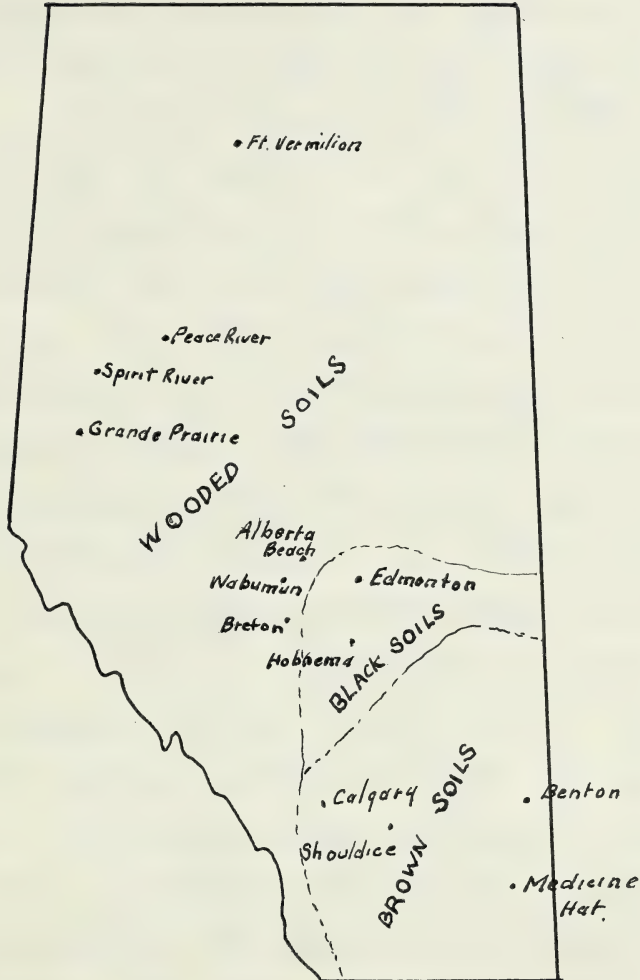
Three of the major soil groups in Alberta are shown on the accompanying map, viz. the brown, the black and the wooded.

The samples used in this investigation have been selected to represent these three soil groups. These soils are grouped according to the kind and degree of weathering they have been subjected to.

In the south of the province we have the brown soils. These soils are the result of weathering under low precipitation and high evaporation. Such conditions are not conducive to excessive growth and accumulation of organic matter. Hence the quantities of organic acids produced will not be very great. It may be seen also that with low precipitation and high evaporation there will be very little water passing downwards. Most of it penetrates a shallow depth and returns to surface by evaporation. This accounts for accumulation of salts near the surface. Under these conditions there will be little or no movement of soil colloids. The exchangeable ^{complex} bases present in these soils are mainly mineral and very little organic matter is present.

The next distinct soil group is the black soils. These soils are produced under more moist conditions than were the brown. Here the evaporation is less, but the downward movement of water is still not excessive. This climate is conducive to active growth and grass is usually the main cover-

SOIL GROUPS OF ALBERTA



ing. Thus it may be seen that only the more soluble parts will be moved. There has been a movement of electrolytes like CaCO_3 , but this has not been excessive, and as a rule there is sufficient to hold the soil colloids.

The third group consists of wooded soils. They compose about two thirds of the area of the province (see map), and are the least fertile of the groups. The wooded soils are produced under more humid conditions than either of the other two. These humid conditions may be brought about by higher precipitation, lower evaporation, poor drainage or a combination of these. The part of the province with wooded soil is perhaps accounted for more by low evaporation rather than by high precipitation. The vegetation on this area is fairly rank, consisting mainly of trees, shrubs, moss and some grass. The soil is maintained in a humid condition, thus providing water for the leaching process. This water is slightly acidic mainly from CO_2 produced in the decay of this organic matter. The leaching power of the water is increased, and thus there is a downward movement of the bases released by the acid conditions. The removal of bases makes the soil colloids less stable. Thus there is a horizon in the upper part of the soil where a removal of bases and colloids have occurred, with subsequent precipitation further down if the soil has been weathered long enough.

The precipitation of Alberta is mostly between 10 and 20 inches, and hence, the differences in soils have been

brought about by lower evaporation.

In general the soil profile is characterized by three general horizons, viz. A, B and C. A is the surface horizon and has undergone some weathering. Below this we find the B horizon which is the horizon of accumulation of degradation products from A. The more or less unaltered horizon underlying the above two is designated by C.

This general grouping of soil horizons is frequently subdivided into many more, viz:

- A₀ - The layer of raw or slightly decayed organic matter.
- A₁ - The horizon of accumulation of decayed products from A₀, if these are not leached away.
- A₂ - The horizon where the leaching has occurred to greatest extent.
- A₃ - The horizon of transition between A₂ and B₁.
- B₁ - The horizon of accumulation of colloidal matter from A horizons.
- B₂ - The horizon of precipitation of electrolytes from above. Mostly as carbonates.
- C - The horizon which has not undergone any appreciable weathering.

Five profiles were taken from the wooded area, three from the black and two from the brown. Those from the wooded area were Fort Vermillion, Ksituan (near Spirit River), Breton, Wabamun and Alberta Beach. The profiles from the black soil's area were from Edmonton (634 and 649) and from Hobbema. The two brown profiles were taken at Shouldice and at Benton.

THE PROBLEM.

This investigation has been planned to compare the Alberta soil groups mentioned, in their vertical distribution of replaceable bases, base-holding capacity and replaceable and hydrolytic acidity. Acidity and base-holding capacity was not determined on the horizon B₂ and those below seeing that these were high in lime carbonate.

EXPERIMENTAL METHODS.

The methods of extraction employed in base exchange work may be classified into three groups, viz:

- (1) Treating the soil with a neutral salt,
- (2) Treating the soil with a dilute acid,
- (3) Electro-dialysis.

The method of treating a soil with a neutral salt seems to be the most popular one. The usual procedure followed is to mix a known quantity of soil with a volume of the salt solution and later filtering it off and leaching with more until a known volume is obtained. There are many slight variations introduced, such as higher temperature, agitation, time of contact, etc. Many solutions have been tried, but the two used most commonly are NH₄Cl and NH₄Ac. The main advantage of these two is that the large excess of the extracting solution can be removed fairly easily by ignition. The main disadvantage is the solution of electrolytes - calcium carbonate in particular.

Workers like Gedroiz (8) and Rice-Williams (27) have used dilute acids for extracting replaceable bases. Dilute HCl and acetic acid are used by these workers. The acetic acid method seems to be fairly satisfactory and compares favorably in results obtained with the other methods. Its big disadvantage is in calcareous soils where excessive solution may occur. This can be said of all methods in which acid extractions are used.

The latest of the methods and one that is used rather extensively by some workers is electro-dialysis. The principle involved in this method is one of separating the products of ionization of the complex by means of an electric current. The replaceable cations accumulate at the cathode and often a semi-permeable membrane is used to keep the complex anions from moving. The cations at the cathode can be determined by ordinary means.

The more or less widespread use of NH_4Cl and NH_4Ac as extracting solutions made it necessary to compare the two salts and choose the one giving the better results. A series of samples were run using each solution and the replaceable calcium and magnesium extracted by each were determined. Four samples of each soil were run using each solution. The results are given in Table 1.

It is seen that the results are fairly consistent throughout and the two salts coincide fairly well. There is some variation in the magnesium obtained in Edmonton B₁ and

known as the "acid test" (8) and (9).

have used dilute acids for extracting the acids.

Dilute HCl and acetic acid are used by the authors.

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ordinary means.

The more or less successful use of this method

as extracting solutions made it necessary to compare the two

acids and choose the one giving the better results. A series

of samples were run using each acid and the results

calculated and compared. The results were as follows.

samples of each acid were run using each acid.

are given in table I.

It is seen that the results are fairly good.

throughout and the two acids showed a fairly good

some variation in the results obtained.

Table 1. Replaceable Calcium and Magnesium Obtained by Ammonium Chloride and Ammonium Acetate Methods.

(Results expressed as milliequivalent per 100 gms. of soil)

Breton B₁

Calcium		Magnesium	
NH ₄ Ac	NH ₄ Cl	NH ₄ Ac	NH ₄ Cl
18.8	19.2	6.7	9.0
18.8	19.0	7.0	8.8
17.6	18.5	6.5	8.7
17.6	18.6	6.3	9.2

Breton A₂

7.5	7.1	1.5	1.5
7.6	6.8	1.4	1.7
7.6	6.8	1.5	1.5
7.7	---	1.5	---

Breton A₁ & o

25.5	23.0	4.6	4.9
25.2	23.9	4.8	5.1
24.5	22.5	4.9	4.7
24.1	22.8	4.9	4.7

Edmonton A₂

24.7	28.3	8.4	8.9
25.2	28.5	9.0	8.7

Edmonton B₁

18.8	18.0	9.5	7.1
18.8	19.4	8.8	7.5
17.1	20.1	9.3	6.9
22.6	19.6	9.4	6.5

Breton B1. However, there is no very significant difference so NH_4Ac was chosen for other reasons as given by Schollenberger (29). Some of the points in its favor that he mentions are:

(1) Ammonium acetate is a neutral salt and has pronounced buffer properties around a pH of 7.

(2) It is easily expelled by a single ignition.

The procedure of extracting a soil sample with the salt solution and the subsequent determination of the bases replaced was as follows:

The air dry soil was mixed and a portion of it crushed to pass a 20-mesh sieve. Twenty-five grams of the sifted soil were weighed out and digested overnight with 500 cc. of normal ammonium acetate (pH 7). The sample was filtered the following day on a Buchner using suction, and then leached with more ammonium acetate till a liter of the leachate was obtained.

A 100-cc. lot (or more if the base contents were low) of the leachate was taken and evaporated on a steam bath. A little HNO_3 was added and when dry the sample was ignited over a Meker burner. The residue was dissolved in hot water with 2-3 cc. of HCl added, and ammonia separation was carried out to remove Al and Fe if present. Calcium was precipitated in the filtrate from the latter as oxalate and titrated with .1N KMnO_4 . The filtrate from calcium determination was evaporated and ignited to remove all ammonium salts. Following this the

residue was evaporated two or three times with H_2SO_4 , ignited at about 700°C . and then the sulphate held by bases determined as BaSO_4 . The sulphate expressed in equivalents represents mostly the Mg and Na-K that have been replaced. Magnesium was determined in a separate quantity of solution by Epperson's method (Treadwell and Hall) after Al, Fe and Ca were removed as in above. The base holding capacity was determined by leaching 25 grams of air-dry soil with a liter of normal CaCl_2 on a Buchner. Following this it was washed free of chlorides and then the calcium fixed was replaced and determined as in the regular method.

Hydrolytic acidity was determined by shaking 25 grams of soil with 250 cc. of normal calcium acetate for an hour filtering and titrating with .1N KOH. Phenolphthalien was used as indicator.

Replaceable acidity was determined by shaking 25 grams of soil with 125 cc. of normal potassium chloride for an hour, filtering and titrating with .1N KOH using phenolphthalien as indicator. This method was checked by using 250 cc. of normal barium chloride in place of potassium chloride. The results obtained did not show any pronounced differences.

EXPERIMENTAL RESULTS.

The results obtained in this investigation are given in Tables 2 and 3. Table 2 shows the vertical distribution of replaceable bases and hydrogen in the various profiles. Table 3 shows the degree of saturation of the various profiles as determined by the three methods.

It was stated in the description of the soils that those in the wooded areas were leached most while those from the brown were least. This has been verified in this investigation.

It should be stated at the beginning that the presence of organic matter in the soil increases the replaceable base content. The complex showing base exchange properties here is the "humic" complex of Gedroiz (8) and the "humus" acid of Hissink (9). This accounts for the correspondingly greater content of replaceable bases in the surface horizons of the black and the wooded soils. On the other hand, the replaceable base content of the surface horizon of the brown soils shows little or no increase over the lower ones.

There is a marked leaching out of replaceable bases in A₂ horizon of the wooded soil. The Alberta Beach profile shows the least leaching in this respect, but it should be said at this point that it does not represent the most leached of our profiles. The horizon of greatest leaching is A₁, but this is shallow, has fair structure and has some organic matter incorporated in it. The A₂ horizons of this profile

The results of these tests are given in Tables 2 and 3. Table 2 shows the variation of the percentage of organic matter in the wood of various species of trees. Table 3 shows the degree of lignification of the wood of various species of trees. It was stated in the description of the tests that those in the wood of trees were less than those in the wood of trees. This has been verified in this paper. The results of these tests are given in Tables 2 and 3. Table 2 shows the variation of the percentage of organic matter in the wood of various species of trees. Table 3 shows the degree of lignification of the wood of various species of trees. It was stated in the description of the tests that those in the wood of trees were less than those in the wood of trees. This has been verified in this paper. The results of these tests are given in Tables 2 and 3. Table 2 shows the variation of the percentage of organic matter in the wood of various species of trees. Table 3 shows the degree of lignification of the wood of various species of trees. It was stated in the description of the tests that those in the wood of trees were less than those in the wood of trees. This has been verified in this paper.

do not show the extremely bleached color of the other profiles, and have a granular structure. This profile is not the best developed one of those that have been studied.

Considering the other four wooded profiles there is a fair amount of replaceable bases in the A₀ horizon. This horizon, however, is not as deep as that of the black soils being from 1 to 5 inches at most. The replaceable bases in A₀ of the wooded soils are between 29.8 and 43.7 M.E., while in the black soils they are between 39.9 and 57.4 M.E. per 100 grams of soil. The difference here is not very great however.

The replaceable base content of A₂ horizons shows the biggest difference between the various soils. In this horizon the total replaceable bases vary between 7.2 and 12.1 M.E. in the better developed wooded profiles. In the black soils the replaceable base content in this horizon is between 22.2 (Hobbema) and 41.4 M.E. (Edmonton 634). There is no apparent leaching in this horizon in the brown soil and actually an accumulation occurs in the Shouldice profile.

There is no great difference in the replaceable base content of B₁ horizons of all the profiles studied, and in the wooded profiles the replaceable bases in this horizon are at least double those found in the A₂ horizon. The B₂ horizon of all the profiles studied show an accumulation of calcium but not of magnesium or of sodium-potassium. It should be said that although small quantities of sodium-potassium could not be determined accurately, an appreciable amount will be indicated.

Table 2. Replaceable Bases, Hydrogen and Base Holding Capacity of Alberta Soils.

(Results expressed as milliequivalents per 100 gms. of soil).

Breton (Wooded)

Horizon	Depth	Cal- cium	Magnes- ium	Total Bases	Sod- ium Potas- sium etc.	Base hold- ing Capac- ity	Hydrogen	
							Replace- able	Hydrol- ytic
A ₀ & 1	0"-2"	24.8	4.9	29.8	0	30.4	0	6.1
A ₂	2"-18"	6.7	2.3	8.7	0	10.5	0	2.2
B ₁	18"-42"	15.1	6.5	20.3	0	28.9	1.8	5.5
C	at 7'	41.5	5.7	46.7	0	----	---	---

Wabamun (Wooded)

A ₀	1"	37.8	5.9	43.7	0	46.8	0	---
A ₁	1"-3"	11.2	2.8	14.0	0	12.3	0	.8
A ₂	3"-12"	8.7	3.0	12.1	0	9.2	0	1.7
B ₁	1'-5'	17.8	7.0	25.5	0	22.7	1.5	4.8
B ₂	at 5'	72.5	7.2	79.9	0	----	---	---

Ft. Vermilion (Wooded)

A ₁	0"-3"	20.0	8.0	31.7	3.7	25.5	.2	---
A ₂	4"-8"	3.7	2.1	7.2	1.4	15.0	2.3	6.0
B ₁	8"-18"	14.8	13.8	35.8	7.0	42.2	0	1.0
B ₂	at 27"	100.0	11.3	112.2	.9	----	---	---

Ksituan (Wooded)

A ₁ & 0	0"-5"	35.6	5.7	41.3	0	40.0	0	---
A ₂	5"-12"	7.5	2.7	10.2	0	9.5	.9	3.0
A ₃	12"-22"	14.1	10.2	24.5	0	28.5	4.5	7.0
B ₁	22"-27"	18.2	12.3	30.9	0	28.9	0	1.7
B ₂	at 30"	46.3	12.0	56.3	-	----	---	---

1. The first part of the report is a general description of the project and its objectives.

2. The second part of the report is a detailed description of the methodology used in the study.

(The following table)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447	2448	2449	2450	2451	2452	2453	2454	2455	2456	2457	2458	2459	2460	2461	2462	2463	2464	2465	2466	2467	2468	2469	2470	2471	2472	2473	2474	2475	2476	2477	2478	2479	2480	2481	2482	2483	2484	2485	2486	2487	2488	2489	2490	2491	2492	2493	2494	2495	2496	2497	2498	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509	2510	2511	2512	2513	2514	2515	2516	2517	2518	2519	2520	2521	2522	2523	2524	2525	2526	2527	2528	2529	2530	2531	2532	2533	2534	2535	2536	2537	2538	2539	2540	2541	2542	2543	2544	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557	2558	2559	2560	2561	2562	2563	2564	2565	2566	2567	2568	2569	2570	2571	2572	2573	2574	2575	2576	2577	2578	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	2589	2590	2591	2592	2593	2594	2595	2596	2597	2598	2599	2600	2601	2602	2603	2604	2605	2606	2607	2608	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	2619	2620	2621	2622	2623	2624	2625	2626	2627	2628	2629	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	2650	2651	2652	2653	2654	2655	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	2671	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	2687	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	2703	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	2735	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765	2766	2767	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	2799	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813	2814	2815	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2831	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	2847	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	2879	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	2895	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909	2910	2911	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925	2926	2927	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941	2942	2943	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957	2958	2959	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	2974	2975	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	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Table 2 (Continued)

Alberta Beach (Wooded)

Horizon	Depth	Cal- cium	Magnes- ium	Total Bases	Sodium Potas- sium etc.	Base hold- ing Capac- ity	Hydrogen	
							Replace- able	Hydrol- ytic
A ₁	2"-5"	11.7	3.9	17.6	2.0	19.0	0	4.1
A ₂	5"-12"	9.9	3.5	15.2	1.9	12.3	0	1.9
A ₂	12"-18"	12.0	3.7	15.9	.2	16.3	0	1.7
B ₁	at 3'	14.4	5.9	21.6	1.3	18.6	0	1.7
B ₂	at 6'	56.0	5.8	63.2	1.4	----	-	---
C	at 6'	48.3	8.0	56.7	.3	----	-	---

Edmonton 634 (Black)

A ₁	1"-12"	50.0	6.4	57.4	1.0	51.0	0	---
A ₂	12"-24"	30.5	8.9	41.4	2.0	37.0	0	1.1
B ₁	24"-30"	27.5	8.2	35.7	0	32.4	0	.7
B ₂	30"-48"	73.0	6.3	79.3	1.5	----	-	---
C		67.0	9.1	76.1	0.7	----	-	---

Hobbema (Black)

A ₁	0"-12"	31.0	10.0	39.9	0	45.6	.2	6.5
A ₂	12"-16"	15.9	6.7	22.2	0	25.4	.0	2.6
B ₁	16"-30"	18.4	8.7	27.3	0	29.7	.0	1.2
B ₂	30"-36"	90.7	9.1	100.2	0	----	--	---
C	5'-6'	28.5	9.4	37.2	0	----	--	---

Edmonton 649 (Black)

A ₁		34.0	7.1	42.2	1.0	----	--	---
A ₂		25.0	8.7	31.6	0	----	--	---
B ₁		18.0	9.2	26.6	0	----	--	---
B ₂		66.5	10.0	74.0	0	----	--	---
C		22.0	9.1	30.0	0	----	--	---

TABLE 1

Continued from page 1

Station	Depth	Time	Temp	Wind	Wave	Current	Remarks
1	10	10:00	10.0	10.0	10.0	10.0	10.0
2	20	10:10	10.1	10.1	10.1	10.1	10.1
3	30	10:20	10.2	10.2	10.2	10.2	10.2
4	40	10:30	10.3	10.3	10.3	10.3	10.3
5	50	10:40	10.4	10.4	10.4	10.4	10.4
6	60	10:50	10.5	10.5	10.5	10.5	10.5
7	70	11:00	10.6	10.6	10.6	10.6	10.6
8	80	11:10	10.7	10.7	10.7	10.7	10.7
9	90	11:20	10.8	10.8	10.8	10.8	10.8
10	100	11:30	10.9	10.9	10.9	10.9	10.9

TABLE 2

Station	Depth	Time	Temp	Wind	Wave	Current	Remarks
1	10	12:00	12.0	12.0	12.0	12.0	12.0
2	20	12:10	12.1	12.1	12.1	12.1	12.1
3	30	12:20	12.2	12.2	12.2	12.2	12.2
4	40	12:30	12.3	12.3	12.3	12.3	12.3
5	50	12:40	12.4	12.4	12.4	12.4	12.4
6	60	12:50	12.5	12.5	12.5	12.5	12.5
7	70	13:00	12.6	12.6	12.6	12.6	12.6
8	80	13:10	12.7	12.7	12.7	12.7	12.7
9	90	13:20	12.8	12.8	12.8	12.8	12.8
10	100	13:30	12.9	12.9	12.9	12.9	12.9

TABLE 3

Station	Depth	Time	Temp	Wind	Wave	Current	Remarks
1	10	14:00	14.0	14.0	14.0	14.0	14.0
2	20	14:10	14.1	14.1	14.1	14.1	14.1
3	30	14:20	14.2	14.2	14.2	14.2	14.2
4	40	14:30	14.3	14.3	14.3	14.3	14.3
5	50	14:40	14.4	14.4	14.4	14.4	14.4
6	60	14:50	14.5	14.5	14.5	14.5	14.5
7	70	15:00	14.6	14.6	14.6	14.6	14.6
8	80	15:10	14.7	14.7	14.7	14.7	14.7
9	90	15:20	14.8	14.8	14.8	14.8	14.8
10	100	15:30	14.9	14.9	14.9	14.9	14.9

TABLE 4

Station	Depth	Time	Temp	Wind	Wave	Current	Remarks
1	10	16:00	16.0	16.0	16.0	16.0	16.0
2	20	16:10	16.1	16.1	16.1	16.1	16.1
3	30	16:20	16.2	16.2	16.2	16.2	16.2
4	40	16:30	16.3	16.3	16.3	16.3	16.3
5	50	16:40	16.4	16.4	16.4	16.4	16.4
6	60	16:50	16.5	16.5	16.5	16.5	16.5
7	70	17:00	16.6	16.6	16.6	16.6	16.6
8	80	17:10	16.7	16.7	16.7	16.7	16.7
9	90	17:20	16.8	16.8	16.8	16.8	16.8
10	100	17:30	16.9	16.9	16.9	16.9	16.9

Table 2 (Continued)

Benton (Brown)

Horizon	Depth	Cal- cium	Magnes- ium	Total Bases	Sod- ium Potas- sium etc.	Base Hold- ing Capac- ity	Hydrogen	
							Replace- able	Hydrol- ytic
A ₁		26.5	5.4	33.7	1.8	41.8	Alk.	.3
A ₂		20.3	5.7	28.3	2.3	22.5	Alk.	0
B ₁		25.8	6.9	33.6	.9	25.3	Alk.	--
B ₂		76.7	11.9	89.0	.4	----	----	--
C		48.0	12.1	62.0	1.9	----	----	--

Shouldice

A ₁	0"-7"	58.0	6.0	64.0	0	60.5	Alk.	--
A ₂	7"-17"	115.0	5.1	120.0	0	93.0	Alk.	--
B ₁		88.5	10.5	99.0	0	95.0	Alk.	--
B ₂		95.5	23.1	121.5	2.9	----	----	--

The wooded profiles taken individually show a replaceable base content in the A_0 horizon that compares well with the A_1 from the black soils. The A_2 horizon shows a decided removal of replaceable bases when it is compared with the other horizons of the same profile or with the A_2 horizon from the black or brown soils. As mentioned previously the B_2 horizon of the wooded profile shows an accumulation of calcium, but not a proportional increase in magnesium.

The black soil profiles, with the exception of A_2 horizon, show a replaceable base content somewhat similar to the wooded profiles. The A_2 horizon of the black soils shows no pronounced removal of bases.

The Benton profile resembles the black soils' profile except that there are less replaceable bases in the A_1 horizon. This is accounted for by the smaller content of organic matter.

All the profiles examined have replaceable calcium, magnesium and sodium-potassium present in normal proportions with possibly the exception of Fort Vermilion. In a normal soil the replaceable bases are found in the following proportions: 75-90% calcium, 10-25% magnesium and a few per cent of sodium-potassium. The Fort Vermilion profile shows a greater content of magnesium and sodium-potassium in proportion to calcium than is found in any of the other profiles.

It should be noted that in the wooded profiles the replaceable Mg has moved in the same proportions as calcium in the A horizons, but there is no corresponding increase of magnesium in the B_2 horizon.

In the black soils the content of replaceable magnesium is about the same throughout the profile, and thus there is no removal of replaceable bases indicated. From this it would seem that all the calcium that has been moved into A₁ and B₂ must have been less stable than the replaceable is, i.e. it must have been calcium carbonate.

There is more correlation between calcium and magnesium even in the B₂ horizon in the brown soils. These soils have calcium carbonate throughout and show that there has been less movement of water soluble calcium than in the black.

These points suggest that,

(1) In the case of wooded profiles the leaching processes have been more severe ^{in A horizon} than in the black soils and actually removed a part of the replaceable bases. There also has been a removal of the complex itself as the base holding capacity is lower than for B₁ of the wooded profile or A₂ of the black.

(2) The movement of calcium in the black soils, which is greater in proportion than the movement of magnesium, indicates that calcium was water soluble rather than replaceable. It is probable that the accumulation of calcium in B₂ was derived from water soluble calcium, as there has not been enough of replaceable calcium lost even in the A₂ of wooded profiles to account for the high accumulation in B₂. There has been no attempt made to distinguish between replaceable and carbonate calcium.

(3) In the brown soils there has been less movement of

In the first place, the removal of the water from the cell is not a simple matter. It is not enough to remove the water from the cell, but it is also necessary to remove the water from the surrounding medium. This is because the water in the surrounding medium is in contact with the water in the cell, and it is possible for the water to move from the surrounding medium into the cell. Therefore, it is necessary to remove the water from the surrounding medium as well as from the cell. This can be done by using a desiccant, such as silica gel, to absorb the water from the surrounding medium. Once the water has been removed from the surrounding medium, it is possible to remove the water from the cell by using a vacuum. This is because the water in the cell is under a higher pressure than the water in the surrounding medium, and it will move from the cell into the surrounding medium when a vacuum is applied.

These points suggest that the removal of water from the cell is a complex process that requires the use of a desiccant to remove the water from the surrounding medium, and a vacuum to remove the water from the cell. In the case of a cell, the removal of water is a critical step in the process of drying the cell. If the water is not removed from the cell, the cell will not dry properly, and it will be difficult to study the cell. Therefore, it is important to understand the process of removing water from the cell, and to use the appropriate techniques to remove the water from the cell. The removal of water from the cell is a complex process that requires the use of a desiccant to remove the water from the surrounding medium, and a vacuum to remove the water from the cell. In the case of a cell, the removal of water is a critical step in the process of drying the cell. If the water is not removed from the cell, the cell will not dry properly, and it will be difficult to study the cell. Therefore, it is important to understand the process of removing water from the cell, and to use the appropriate techniques to remove the water from the cell.

water soluble calcium, and there is a better proportion of calcium and magnesium in all horizons, even the B₂.

The soils of Alberta compare very favorably in replaceable base content with some of the other soils reported. Bray (4) reported on a number of Illinois surface soil samples. He found the replaceable base-content to be under 33 M.E. per 100 grams of soil. Page and Williams (22) determined the replaceable bases in the surface soil of Broadbalk field at Rothamsted, and found them to be between 12 and 16 M.E. In Alberta the replaceable bases of the A horizon is between 7.2 and 60 M.E.

In studying the degree of saturation of the various horizons it was found that the CaCl_2 method did not give very consistent results. Most of the soils showed a smaller base-holding capacity by this method than there was of replaceable bases. This is probably due to removal of electrolytes by solution and of complex by hydrolysis in the course of leaching and washing. This method is not satisfactory for showing up the small degree of unsaturation that is found in these soils. However, for the horizons A₂ from Fort Vermilion, A₃ from Ksituan and B₁ from Breton it does indicate some unsaturation. This is probably due to the larger quantity of acidity found in these horizons.

The method which seemed to be the most satisfactory was where the base-holding capacity was taken as the sum of total replaceable bases and hydrolytic hydrogen. The hydrolytic hydrogen should indicate the quantity of bases it has replaced

to a larger degree than would replaceable hydrogen.

The most pronounced difference in the degree of saturation is noticed in the A₂ horizon. In the black soil this horizon is about 95% saturated in the Edmonton profile and about 90% in the Hobbema. In the wooded profiles it is between 55 - Fort Vermilion and 88 - Wabamun. Even this horizon, which is the most leached, does not show any appreciable unsaturation. This accounts for the more or less neutral reaction of the wooded soils. From this it could be assumed that the removal of the alumino-silicate complex from the A₂ horizons of the wooded soil has been as colloidal solution and not as oxides of Al and Fe. This is taken to be the case as the conditions are not very acid and thus the complex should not decompose. However, it is probable that the complex is made less stable physically and enter a colloid solution condition by being made acidic. The lack of ortstein layer also shows that there is no Al or Fe as oxides. The accumulation of SiO₂ in the A₂ horizon is probably derived from disintegration of feldspar rocks into the base-exchange complex and SiO₂. This was found by Truog and Chucka (30) in weathering of feldspars.

The A₀ horizon of the wooded and the A₁ of the black soils show about the same degree of both hydrolytic and replaceable acidity. There is considerably more hydrolytic acidity found in this horizon than replaceable acidity, so the reaction does not indicate conditions acid to a pH of 7. The

Table 3. Degree of Saturation of Alberta Soils[#].

Breton (Wooded)

Horizon	Total Bases	Base Holding Capacity	Ratio ₁	Replaceable Hydrogen	Ratio ₂	Hydrolytic Hydrogen	Ratio ₃
A ₁ & o	29.8	30.4	99	0	100	6.1	83
A ₂	8.7	10.5	83	0	100	2.2	80
B ₁	20.3	28.9	70	1.8	92	6.5	78

Wabamun (Wooded)

A ₀	43.7	46.8	93	.2	99	---	--
A ₁	14.0	12.3	114	0	100	.8	95
A ₂	12.1	9.2	132	0	100	1.7	88
B ₁	25.5	22.7	112	1.5	96	4.8	84

Ft. Vermilion (Wooded)

A ₁	31.7	25.5	124	.2	99	---	--
A ₂	7.4	15.0	50	2.3	76	6.0	55
B ₁	35.5	42.2	83	0	100	1.0	97

Ksituan (Wooded)

A ₁ & o	41.3	40.0	102	0	100	---	--
A ₂	10.2	9.5	108	.9	92	3.0	77
A ₃	24.5	28.4	87	4.5	84	7.5	77
B ₁	30.9	28.9	107	0	100	1.7	95

$$\# \text{ Ratio}_1 = \frac{\text{Total Bases}}{\text{Base holding capacity}} \times 100$$

$$\text{Ratio}_2 = \frac{\text{Total Bases}}{\text{Total Bases} + \text{Replaceable Hydrogen}} \times 100$$

$$\text{Ratio}_3 = \frac{\text{Total Bases}}{\text{Total Bases} + \text{Hydrolytic Hydrogen}} \times 100$$

Table 1. Summary of data for the 1960-1961 season.

Table 2. Summary of data for the 1961-1962 season.

Station	1960-1961	1961-1962	1962-1963	1963-1964	1964-1965	1965-1966	1966-1967
1	1.2	1.5	1.8	2.1	2.4	2.7	3.0
2	1.5	1.8	2.1	2.4	2.7	3.0	3.3
3	1.8	2.1	2.4	2.7	3.0	3.3	3.6
4	2.1	2.4	2.7	3.0	3.3	3.6	3.9
5	2.4	2.7	3.0	3.3	3.6	3.9	4.2
6	2.7	3.0	3.3	3.6	3.9	4.2	4.5
7	3.0	3.3	3.6	3.9	4.2	4.5	4.8
8	3.3	3.6	3.9	4.2	4.5	4.8	5.1
9	3.6	3.9	4.2	4.5	4.8	5.1	5.4
10	3.9	4.2	4.5	4.8	5.1	5.4	5.7

Table 3. Summary of data for the 1967-1968 season.

Station	1967-1968	1968-1969	1969-1970	1970-1971	1971-1972	1972-1973	1973-1974
1	1.2	1.5	1.8	2.1	2.4	2.7	3.0
2	1.5	1.8	2.1	2.4	2.7	3.0	3.3
3	1.8	2.1	2.4	2.7	3.0	3.3	3.6
4	2.1	2.4	2.7	3.0	3.3	3.6	3.9
5	2.4	2.7	3.0	3.3	3.6	3.9	4.2
6	2.7	3.0	3.3	3.6	3.9	4.2	4.5
7	3.0	3.3	3.6	3.9	4.2	4.5	4.8
8	3.3	3.6	3.9	4.2	4.5	4.8	5.1
9	3.6	3.9	4.2	4.5	4.8	5.1	5.4
10	3.9	4.2	4.5	4.8	5.1	5.4	5.7

Table 4. Summary of data for the 1974-1975 season.

Station	1974-1975	1975-1976	1976-1977	1977-1978	1978-1979	1979-1980	1980-1981
1	1.2	1.5	1.8	2.1	2.4	2.7	3.0
2	1.5	1.8	2.1	2.4	2.7	3.0	3.3
3	1.8	2.1	2.4	2.7	3.0	3.3	3.6
4	2.1	2.4	2.7	3.0	3.3	3.6	3.9
5	2.4	2.7	3.0	3.3	3.6	3.9	4.2
6	2.7	3.0	3.3	3.6	3.9	4.2	4.5
7	3.0	3.3	3.6	3.9	4.2	4.5	4.8
8	3.3	3.6	3.9	4.2	4.5	4.8	5.1
9	3.6	3.9	4.2	4.5	4.8	5.1	5.4
10	3.9	4.2	4.5	4.8	5.1	5.4	5.7

Table 5. Summary of data for the 1981-1982 season.

Table 6. Summary of data for the 1982-1983 season.

Table 7. Summary of data for the 1983-1984 season.

Table 3 (Continued)

Alberta Beach (Wooded)

Horizon	Total Bases	Base Hold- ing Capac- ity	Ratio ₁	Replace- able Hydrogen	Ratio ₂	Hydroly- tic Hydrogen	Ratio ₃
A ₁	17.6	19.0	93	0	100	4.1	81
A ₂	15.2	12.3	123	0	100	1.9	89
A ₂	15.9	16.3	98	0	100	1.7	90
B ₁	21.6	18.6	116	0	100	1.7	91

Edmonton 634 (Black)

A ₁	57.4	51.0	112	0	100	---	--
A ₂	41.4	37.0	110	0	100	1.1	98
B ₁	35.7	32.4	112	0	100	.7	98

Hobbema (Black)

A ₁	39.9	45.6	87	.2	99	6.5	86
A ₂	22.2	25.4	88	0	100	2.6	89
B ₁	27.3	29.7	92	0	100	1.2	96

Benton (Brown)

A ₁	33.7	41.8	81	Alk.	100+	---	--
A ₂	28.3	22.5	127	Alk.	100+	---	--
B ₁	33.6	25.3	136	Alk.	100+	---	--

Shouldice (Brown)

A ₁	64.0	60.5	106	Alk.	100+	---	--
A ₂	120.0	93.0	140	Alk.	100+	---	--
B ₁	99.0	95.0	104	Alk.	100+	---	--

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degree of saturation of the A_0 horizon of all these soils is still high, being above 80.

The B_1 horizon of the black soils shows very little hydrolytic or replaceable acidity. On the other hand the A_3 horizon from Ksituan, B_1 from Breton and B_1 from Wabamun all show a fair degree of hydrolytic acidity. This presence of hydrolytic acidity in the A_3 and B_1 horizons of the wooded profile is probably due to the precipitation of somewhat acid colloids brought down in the course of leaching. These colloids are organic and inorganic, the former being indicated by an increase in nitrogen content in this horizon.

From the above it could be assumed that in case of the black soils the horizons A_2 and B_1 have been subjected to less acid than A_1 . The hydrolytic acidity of A_1 shows that there has been as much acid produced here as in the wooded soils, but it did not permeate the lower horizons as much as it did in the case of wooded soils.

The apparent lack of hydrolytic acidity in the brown soils is due to very little organic acids being produced, seeing that there is only a scant vegetation.

Although the degree of acidity in these soils is not very great the hydrolytic always exceeds the replaceable. Then since hydrolytic acidity has been extracted with an alkaline salt it indicates that the soil contains acid that could not be extracted with neutral salts. Apparently the soil was originally on the alkaline side of pH of 7, and in the course

of leaching has fixed some acids, but not sufficiently to create acid condition. Hydrolytic hydrogen can be said to resemble the hydrogen in Na_2HPO_4 . It should be noted that the proportion of hydrolytic acidity is much greater in A_2 and B_1 horizons of the wooded soils than it is in the black. Likewise there is some replaceable acidity noticed in the wooded profiles from Ksituan, Fort Vermilion, Breton and Wabamun. This shows that the wooded soils have been subjected to more acid in the course of leaching. Gedroiz (8) brings out an important point in this relation. He states that a complex will actually absorb H ions from pure water with subsequent leaching away of bases. Thus it may be possible that the acid found was derived not from acid leaching but from excessive leaching, or which is more reasonable, a combination of the two.

It is seen from the above discussion that only the wooded soils have any replaceable hydrogen present. Thus according to Gedroiz system of classification these wooded soils fall into the podsol group. The black and the brown soils fall into the chernozem group. It appears, however, that the black soils are approaching a podsol condition. This is based on the fact that Hobbema profile has a small quantity of replaceable hydrogen in its A_2 horizon.

CONCLUSIONS.

The following conclusions have been drawn from this investigation.

(1) Alberta soils are high in replaceable bases compared to Illinois and Rothamsted soils, and are normal in their calcium, magnesium and sodium-potassium ratio.

(2) The soils from the wooded area show a distinct removal of replaceable bases in the A₂ horizon.

(3) The replaceable bases content found in the A₀ of the wooded soils is in the same class as the A₁ from the black soils, only that A₀ is not as deep.

(4) The wooded soils have been subjected to much more leaching than the black soils have been. Hydrolytic acidity is found in greater portions in the A₂ and B₁ horizons of the wooded soils than in the black. There is little or no hydrolytic acidity in the B₁ horizon of the black soils.

(5) There has been a precipitation of organic and mineral colloids showing hydrolytic acidity in the B₁ horizon of the wooded soils.

(6) In the black soils there has been considerable acidity produced, but it is all confined to the surface horizon, i.e. A₁. This is due to less excessive leaching of water into the lower horizons.

(7) The brown soils do not show any decided leaching and show no fixed acidity - they react alkaline to neutral salts.

The following conclusions are drawn from this investigation.

(1) Alberta soils are high in organic matter, especially in the forested areas.

(2) The soils from the forested areas are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(3) The soils from the forested areas are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(4) The non-forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(5) The forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(6) The forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(7) The forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(8) The forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(9) The forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(10) The forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(11) The forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(12) The forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(13) The forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(14) The forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(15) The forest soils are high in organic matter, especially in the forested areas, and are high in organic matter, especially in the forested areas.

(8) The movement of bases in black soils has been mostly calcium. The normal ratio of replaceable calcium to magnesium in the horizons A₂ and B₁ indicates that all the calcium moved was soluble in water or slightly acid solution. This calcium exists mostly as calcium carbonate.

(9) The accumulation of calcium in B₂ horizons has been mostly carbonate calcium and not replaceable. There has not been sufficient replaceable calcium removed to account for the high replaceable calcium content of B₂ horizon, even in the wooded soils.

(10) The soils of Alberta were originally alkaline and have not fixed sufficient acid to react acid. Only the wooded soils show any replaceable acidity below a pH of 7. The hydrolytic acidity shows how much acid has been fixed in the course of leaching.

(11) The movement of base exchange complex as noticed in the wooded soils has been as colloidal material. This complex has not decomposed into its oxides, but has been made less stable physically due to leaching of electrolytes and absorption of acid by the complex.

(12) The excess silica of the A₂ horizon of the wooded soils has been derived from disintegration of rocks rather than decomposition of the complex into its oxides. Feldspar gives silica and an alumino-silicate which has base-exchange properties in the course of weathering.

(13) The wooded soils used in this investigation fall

into the podsol group according to Gedroiz system of soil classification.

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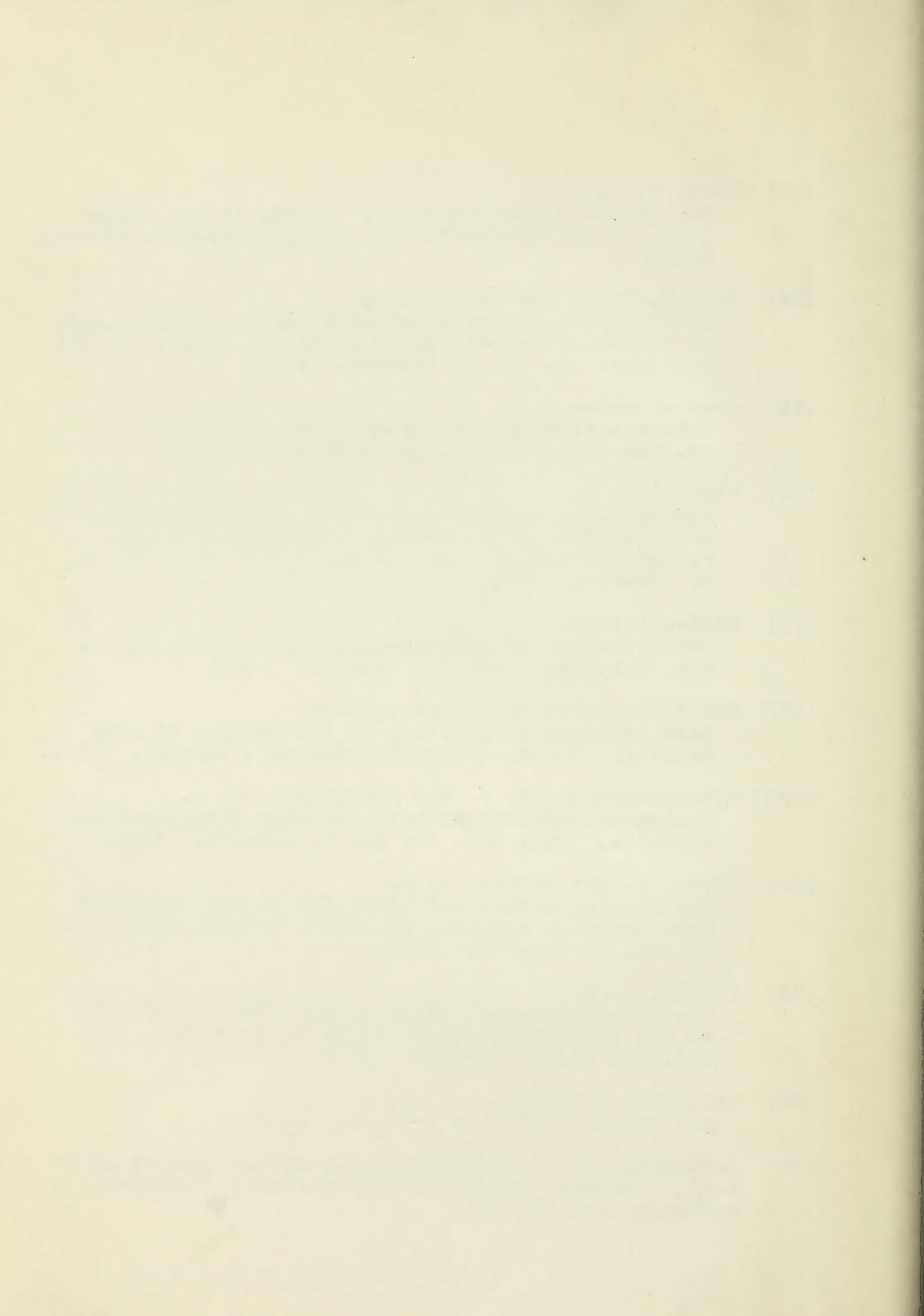
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